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(71) Applicant *(for all designated States except US)*: CAMBRIDGE INDUSTRIES [GB/GB]; Cambridge House, Crompton Way, Irvine, Ayrshire KA11 4HU (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : FLYNN, Stephen, John [GB/GB]; 19 Castle Road, Dunure, Ayrshire KA7 4LY (GB). BAIRD, Andrew, Patrick [GB/GB]; 1 Dinmurchie Road, Troon, Ayrshire KA10 7JU (GB).

(74) Agents: McCALLUM, William, Potter et al.; Cruikshank & Fairweather, 19 Royal Exchange Square, Glasgow G1 3AE (GB).

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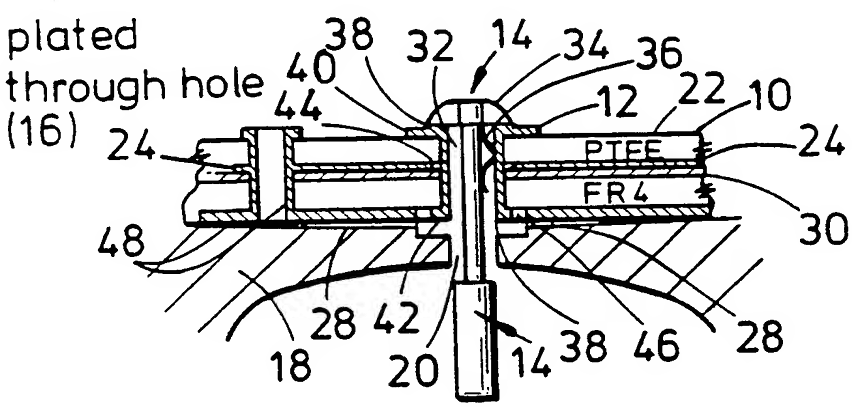

(57) Abstract

An RF waveguide signal transition apparatus for minimising leakage at RF frequency is described which consists of providing a plurality of plated through-holes (16) of blind holes in a circuit board (10). The plated holes (16) are disposed on the circumference of a circle around the RF waveguide to microstrip transition of probe (14) and each of the plated holes (16) is connected to a ground plane (24). The size of distribution of the plated holes provides a barrier to signal leakage at RF frequencies in the range 10.95-11.7 GHz and they also provide a transition impedance similar to the 50 ohm characteristic impedance providing satisfactory matching and minimising leakage into the board. The apparatus can also be used to minimise leakage from microstrip to microstrip transitions passing through the circuit board.

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RF WAVEGUIDE SIGNAL TRANSITION APPARATUS

The present invention relates to a waveguide to microstrip transition where a waveguide probe is passed from the waveguide through a circuit board before connecting to the microstrip line. The invention also relates to a microstrip to microstrip transition where a signal carried on the microstrip requires to pass through a multilayer circuit board. The invention is particularly related to transitions for use with radio frequency signals.

In a double-sided or multilayer circuit board which is connected to a waveguide, one way in which signals may be taken from the waveguide to the board requires a probe to pass through the waveguide wall and the board so that when the probe protrudes into the waveguide it will pick up signals propogating in the waveguide. In order for such an arrangement to work properly it is necessary to connect the probe to a microstrip conductor. This is typically done by drilling a hole in the circuit board prior to etching the board then fitting a probe in the drilled hole. This arrangement would provide a low loss transition as long as there is no or little loss of signal into the board's materials, such as the PTFE and FR4, and the probe passing through the board's materials does not present too great a mismatch. However, with the

arrangement shown in Fig. 1 the transition is lossy resulting in over 1dB. of loss. This is unacceptable for a low-noise receiver. It is believed that the ground planes on each side of the FR4 act as a parallel plate waveguide into which signals can couple resulting in extra losses and also changing the impedance of the transition causing a mismatch to the microstrip line; any mismatch will also result in loss of signal.

An object of the present invention is to provide an improved transition which obviates or mitigates at least one of the aforementioned disadvantages.

In its broadest aspect this is achieved by providing a plurality of plated holes in a circuit board and disposing these around the RF waveguide or microstrip to microstrip transition and connecting these plated holes to ground. This results in a transition with a substantially improved performance which has much less loss than the prior art arrangement.

In a preferred arrangement all the holes, including the hole receiving the probe are plated through-holes for reasons of simplicity and cost. In an alternative arrangement blind holes can be used The plurality of holes can be provided in a multilayer board or in a double-sided board.

Conveniently, four of these plated through-holes are disposed around the waveguide or microstrip to microstrip probe and are ideally placed on the circumference of a

circle centred on the probe. The holes are in close proximity to the feedthrough.

According to one aspect of the present invention there is provided an RF waveguide to circuit transition wherein a waveguide probe passes through a circuit board and is connected to a signal conductor on the circuit board, the circuit board having a ground plane, a plurality of plated holes disposed in proximity to and spaced around the waveguide probe such that the transition impedance is as close as possible to the characteristic impedance of the microstrip line, said plated holes being coupled to the ground plane to minimise leakage of signals carried by the probe into the board. Preferably, the holes are plated through-holes. Alternatively, the holes are plated blind holes. Preferably also the probe hole is plated.

Preferably also, four plated holes are disposed around the periphery of the waveguide probe. Conveniently said plated holes being placed on the circumference of a circle centred on the probe. Alternatively, three, five or any suitable number of holes may be used to achieve satisfactory performance.

It has been found that four such plated through-holes provide satisfactory results, but the spacing of the holes is important in relation to the feed-through, holes requiring to be close in proximity to the feed-through. The required proximity and spacing of the holes is

frequency dependent. It is has been found that if the holes are too close, then a transition impedance may be low with respect of the commonly-used characteristic impedance of 50 ohms and if too far away would allow unacceptable leakage into the board. In addition, the spacing of holes in relation to each other is also important as the size of the gap between the plated holes and the frequency of the RF signal dictates how much RF signal can pass between the holes. Whilst various examples of hole size, hole diameter and spacing are given, it will be understood that these parameters may be obtained in particular cases by routine experimentation.

According to another aspect of the present invention there is provided a method of minimising leakage of RF signals from a waveguide to conductor transition passing through a circuit board adjacent said waveguide and in which a probe extends through the circuit board and waveguide wall into the waveguide, such method comprising the steps of,

disposing a plurality of holes in said circuit board around the periphery of said probe,

plating or otherwise covering the side of each hole with a conductive material, and

connecting the plated holes to a ground plane.

Preferably, said method involves providing through-holes in said circuit board. Alternatively, said method involves providing blind holes in said circuit

board.

Conveniently, the circuit board is a multilayer board.

According to another aspect of the invention there is provided a circuit board for receiving a probe for insertion into a waveguide to receive signals therefrom and transfer these signals to said circuit board, said circuit board comprising, at least one conductor for connection to said probe, a ground plane,

a through-hole for receiving said probe,

a plurality of plated holes disposed in said circuit board around the periphery of said plated through hole, said plated holes being connected to said ground, said holes being proportioned and dimensioned so that leakage of signals into the circuit board from the probe is minimised.

Preferably, the through-hole for receiving the probe is plated.

According to another aspect of the present invention there is provided a circuit board transition for minimising leakage of signals carried on microstrip conductors, which signals pass through said circuit boards, said circuit board transition comprising a first microstrip location on one side of said circuit board for carrying a signal, a second microstrip location on the other side of the board for receiving said signal, signal conducting means passing through said board and connected to said first and said second microstrip conductors, a

ground plane disposed in said circuit board, a plurality of plated through holes or blind holes disposed in said circuit board about the periphery of said signal conducting means, said plated through holes or blind holes being coupled to said ground plane to minimise leakage of said signal passing through said board between the first and second microstrip.

These and other aspects of the invention will become apparent from the following description when taken in combination with the accompanying drawings in which:-

Fig. 1 is a plan view of a waveguide to microstrip transition showing a plurality of holes disposed around a probe coupled to a microstrip line,

Fig. 2 is a cross-section taken in the lines A-A through the waveguide to microstrip transition shown in Fig. 1 in accordance with an embodiment of the present invention;

Fig. 3 is an enlarged view Fig. 1 showing the spacing and dimension of the plated through-hole in accordance with the embodiment of the present invention;

Fig. 4 is a view similar to Fig. 2 depicting plated blind holes, and

Fig. 5 is a sectional view similar to Fig. 2 of a microstrip to microstrip transition connection through a three layer circuit board.

Reference is first made to Fig. 1 of the drawings which depicts a top view of a circuit board generally

indicated by reference numeral 10 which has a microstrip line 12 terminating in a plated through-hole and probe 14. Four plated through-holes 16 are disposed around the probe 14 as shown. Reference is now made to Fig. 2 of the drawings which is a cross-sectional view on the lines A-A shown in Fig. 1 and shows a cross-section through one of the plated through-holes 16 and the probe 14.

The circuit board 10 shown coupled to the top of a waveguide 18 which has an aperture 20 therein for receiving the waveguide probe 14. The circuit board 10 is a multilayer laminate and has an upper polytetrafluoroethylene (PTFE) layer 22 then a copper ground plane 24 bonded thereto, a bottom layer of FR4, which is a fibreglass resin material, and a copper bottom ground pad 28 which is in electrical and mechanical contact with the waveguide 18. The PTFE and ground plane 22 and 24 are bonded to the FR4 by a prepreg or glue layer 30. The structure of microstrip boards are well-known and the manufacture of such a board begins with the provision of the PTFE board and FR4 board which has copper on both sides. The copper is then etched off from one side of the FR4 and the PTFE and FR4 are bonded with prepreg under high pressure.

The probe 14 passes through plated through-hole 32 which registers with aperture 20 and the probe 14 is soldered to the plating at the top of the board by solder joint 34 as shown. The waveguide probe includes a kinked

portion 36 which abuts the plated sides 38 of the hole to secure the waveguide probe 14 in the centre of the hole 32. Plating of hole 32 is achieved by drilling the through-hole in the board 10 prior to etching. Plating results in conductive material, i.e. copper, is on the insides of the hole 32 shown as well as on the top 40 and bottom surface 42 of the board 10. It will be appreciated that there are circumferential gaps 44,46 between the plating of the through-hole and the ground plane 24 and ground pad 28 respectively; these gaps preventing shorting of the signal from the probe to ground.

Each plated through-hole 16 is plated on the inside in the same way as the through-hole 32 for the waveguide probe 14. In this case the plating 48 is continuous with and merges with the ground plane 24 and the ground pad 28. These holes are made by drilling prior to etching in the same way as the waveguide probe hole. The four holes 16 are disposed about the periphery of the probe 14 and act as a barrier to leakage of the RF signal from the probe, thus limiting leakage into the PTFE and FR4 material of the circuit board. For frequencies in the range of (10.95-11.7) GHertz., the holes are spaced apart as shown in Fig. 3. Each plated through-hole 16 has an internal diameter of 0.5mm and the probe hole 32 has an internal diameter of 1.0mm. The opening in the ground between boards is 3.5mm in diameter. The size of hole and hole distribution has been found to provide a suitable

leakage barrier to RF frequencies in the aforementioned range and they also provide a transition impedance which is similar to the characteristic impedance of 50 ohms providing satisfactory matching and minimising leakage into the board. It will be appreciated that the spacing of holes in relation to each other is of importance because the size of the gap between the holes dictates how much RF signal can pass between the holes. Although the hole diameter does influence the passage of unwanted signal, the dominant factor is the spacing between the edge of the holes.

It will be appreciated that any form of conductive material around the probe would be adequate the reduce leakage into the board material as long as only small or no gaps were left between the conductive sections.

It will also be appreciated that various modifications may be made to the embodiment hereinbefore described without departing from the scope of the invention. For example, the holes 16 do not require to pass through the entire circuit board. Because it has been found that the FR4 is the dominant factor for providing leakage into the circuit board in comparison to the PTFE layer, blind holes may also be used resulting in holes in the FR4 material, but not through the PTFE. This is best seen in Fig. 4 of the drawings where like numerals refer to like parts of Figs. 1 to 3 and where blind holes 50 pass through the FR4 material only, instead

of the through-plated vias. The blind holes 50 in the FR4 material are formed by drilling holes through the FR4 after laminating the boards but prior to plating the holes. Holes 50 are connected to the ground plane 24 at the FR4/PTFE junction 52. In addition, the size and spacing of the holes are dependent on the signal frequency used. In addition, it will be understood that other values of characteristic impedance may be used, for example, 75 ohms, as required. The holes do not require to be spaced around the probe on the circumference of a circle; this is just a convenient way to space the holes. An interconnection can be formed on a multilayer circuit board using similar principles and structure to the waveguide to conductor RF transition. This is shown in Fig. 5 of the drawings. In this case a circuit board 60 has 3 layers, layer 1, layer 2 and layer 3, and a copper microstrip line 62 on layer 1 is connected to a copper microstrip line 64 on layer 3 via copper plated through hole 32. The layers 1,2 and 2,3 are separated by prepreg material 30. As with the RF transition a plurality of plated through holes or blind holes can be placed around the interconnection holes to avoid loss of the signal into layer 2. In addition, the microstrip to microstrip transition can use either plated through holes or blind holes sized and spaced as appropriate to minimise leakage.

CLAIMS

1. An RF waveguide to circuit transition wherein a waveguide probe passes through a circuit board and is connected to a signal conductor on the circuit board, the circuit board having a ground plane, a plurality of plated holes disposed in proximity to and spaced around the waveguide probe such that the transition impedance is as close as possible to the characteristic impedance of the microstrip line, said plated holes being coupled to the ground plane to minimise leakage of signals carried by the probe into the board.

2. An RF waveguide as claimed in claim 1 wherein the holes are plated through holes.

3. An RF waveguide as claimed in claim 1 wherein the holes are plated blind holes.

4. An RF waveguide as claimed in any preceding claim where the probe hole is plated.

5. An RF waveguide as claimed in any preceding claim wherein four plated holes are disposed about the periphery of the waveguide probe.

6. An RF waveguide as claimed in any preceding claim

wherein said plates holes are placed on the circumference of a circle centre on the probe.

7. An RF waveguide as claimed in any preceding claim wherein said circuit board is a multilayer board.

8. A method of minimising leakage of RF signals from a waveguide to conductor transition passing through a circuit board adjacent said waveguide and in which a probe extends through the circuit board and waveguide wall into the waveguide, such method comprising the steps of,

disposing a plurality of holes in said circuit board around the periphery of said probe,

plating or otherwise covering the side of each hole with a conductive material, and

connecting the plated holes to a ground plane.

9. A method as claimed in claim 8 including the step of providing through-holes in said circuit board.

10. A method as claimed in claim 8 including the step of providing blind holes in said circuit board.

11. A circuit board for receiving a probe for insertion into a waveguide to receive signals therefrom and transfer these signals to said circuit board, said circuit board comprising, at least one conductor for connection to said

probe, a ground plane,

a through-hole for receiving said probe,

a plurality of plated holes disposed in said circuit board around the periphery of said plated through hole, said plated holes being connected to said ground, said holes being proportioned and dimensioned so that leakage of signals into the circuit board from the probe is minimised.

12. A circuit board as claimed in claim 11 wherein said through hole for receiving the probe is plated.

13. An RF waveguide to microstrip transition for use with a double-sided or multilayer circuit board wherein a waveguide probe passes through the circuit board and is connected to a signal conductor on the circuit board comprising a plurality of plated holes in the circuit board and disposing said holes around the RF waveguide to microstrip transition, a ground plane, and means connecting said plated holes to ground.

14. An RF waveguide to microstrip transition as claimed in claim 13 wherein said plated holes are through-holes.

15. An RF waveguide to microstrip transition as claimed in claim 13 wherein said plated holes are blind holes.

16. A circuit board transition for minimising leakage of signals carried on microstrip conductors, which signals pass through said circuit boards, said circuit board transition comprising a first microstrip location on one side of said circuit board for carrying a signal, a second microstrip location on the other side of the board for receiving said signal, signal conducting means passing through said board and connected to said first and said second microstrip conductors, a ground plane disposed in said circuit board, a plurality of plated through holes or blind holes disposed in said circuit board about the periphery of said signal conducting means, said plated through holes or blind holes being coupled to said ground plane to minimise leakage of said signal passing through said board between the first and second microstrip.

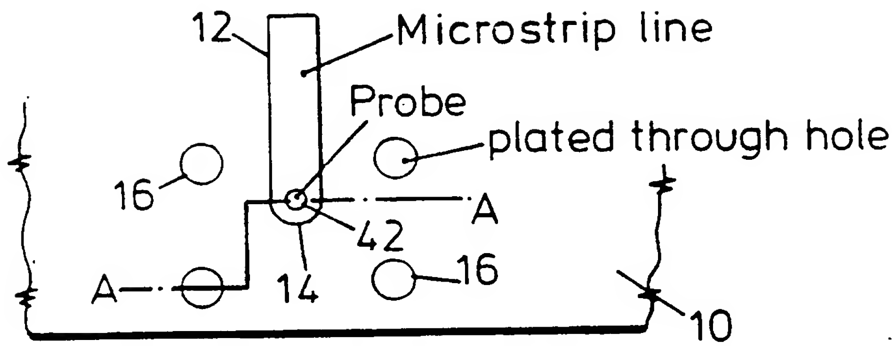
12
Microstrip line
Probe
plated through hole
16
A
42
A
14
16
10

FIG.1

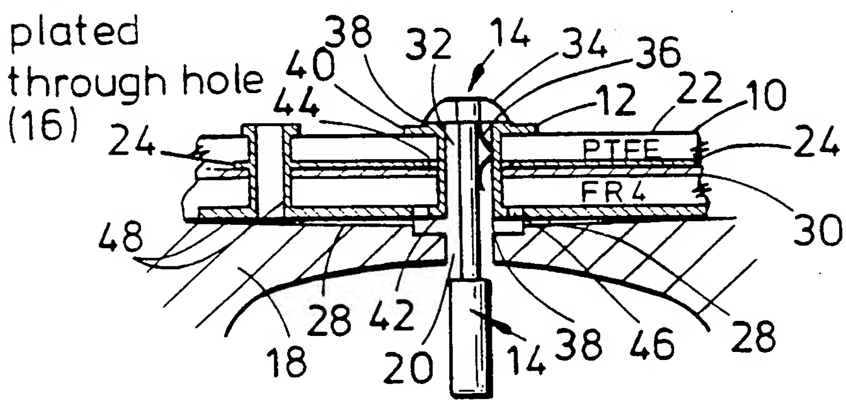
plated
through hole
(16)
38
40
44
32
14
34
36
12
22
10
24
PTFE
24
FR4
30
48
28
42
18
20
14
38
46
28

FIG.2

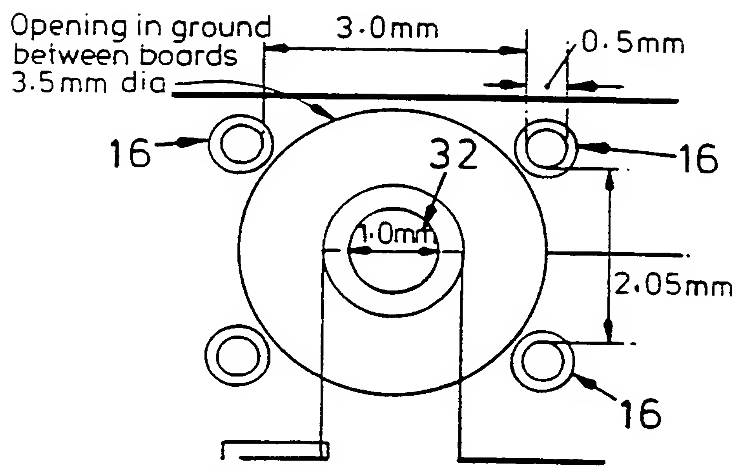

FIG.3

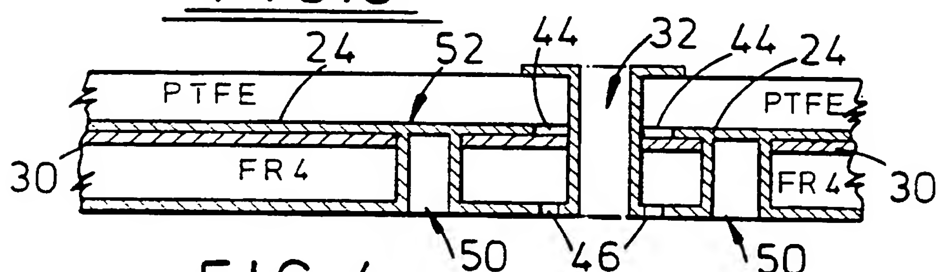

FIG.4

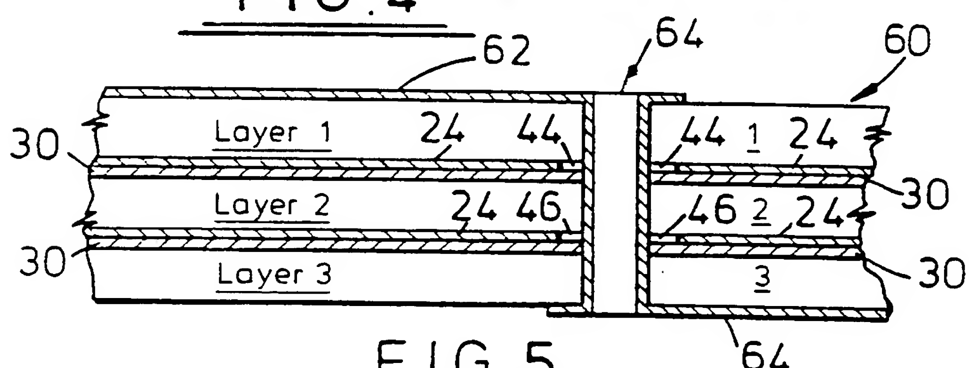

FIG.5

SUBSTITUTE SHEET

INTERNATIONAL SEARCH REPORT

International Applicat PCT/GB 93/01369

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H01P1/04; H01P5/107

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	H01P

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	US,A,4 562 416 (SEDIVEC) 31 December 1985	1,2,4,6, 8,9, 11-14
Y	see the whole document	5,7,16
Y	PATENT ABSTRACTS OF JAPAN vol. 6, no. 32 (E-96)(910) 26 February 1982 & JP,A,56 153 802 (NIPPON DENKI K.K.) 28 November 1981 see abstract	5
Y	EP,A,0 318 311 (GENERAL ELECTRIC COMP.) 31 May 1989 see column 7, line 9 - column 8, line 8; figure 2B	7,16

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° Special categories of cited documents : [10]

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IV. CERTIFICATION

1

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
15 SEPTEMBER 1993	30.09.93
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	DEN OTTER A.M.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	US,A,2 877 429 (SOMMERS ET AL.) 10 March 1959 see the whole document ---	1,2,8,9, 11,13,14
A	US,A,4 846 696 (MORELLI ET AL.) 11 July 1989 see column 5, line 56 - column 6, line 18; figures 21,22 ---	1,8,11, 13,16
A	PATENT ABSTRACTS OF JAPAN vol. 8, no. 131 (E-251)(1568) 19 June 1984 & JP,A,59 040 702 (MATSUSHITA DENKI SANGYO K.K.) 6 March 1984 see abstract -----	1,8,11, 13

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 9301369 SA 75944

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A-4562416	31-12-85	None		
EP-A-0318311	31-05-89	US-A-	4816791	28-03-89
US-A-2877429		None		
US-A-4846696	11-07-89	AU-A-	3455089	21-12-89
		EP-A-	0347316	20-12-89
		JP-A-	2039601	08-02-90

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82